DRYING OF STICKY MATERIALS- RELEVANCE TO GLASS TRANSITION TEMPERATURE (Tg)

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Stickiness issues:

- Stickiness on the drier wall (spray drying)
- Wet and plastic appearance
- Agglomeration and clumping in packing container
- Operational problems

Products exhibiting stickiness

Products with high amount of sugars or organic acids

- Fruit juices/pieces/purees/leathers
- Honey
- Molasses
- Whey (acid or sweet)
- High DE maltodextrins (DE>30)
- Pure sugars- lactose, glucose, sucrose, fructose
- High acid foods

High fat foods

Major factors causing stickiness

- High hygroscopicity
- High solubility
- Low melting point temperature
- Low glass transition temperature (related to thermoplasticity)

Glass Transition Approach

- Recent approach to describe stickiness
- Applied to spray drying

Physical properties of sugars and stickiness behaviour

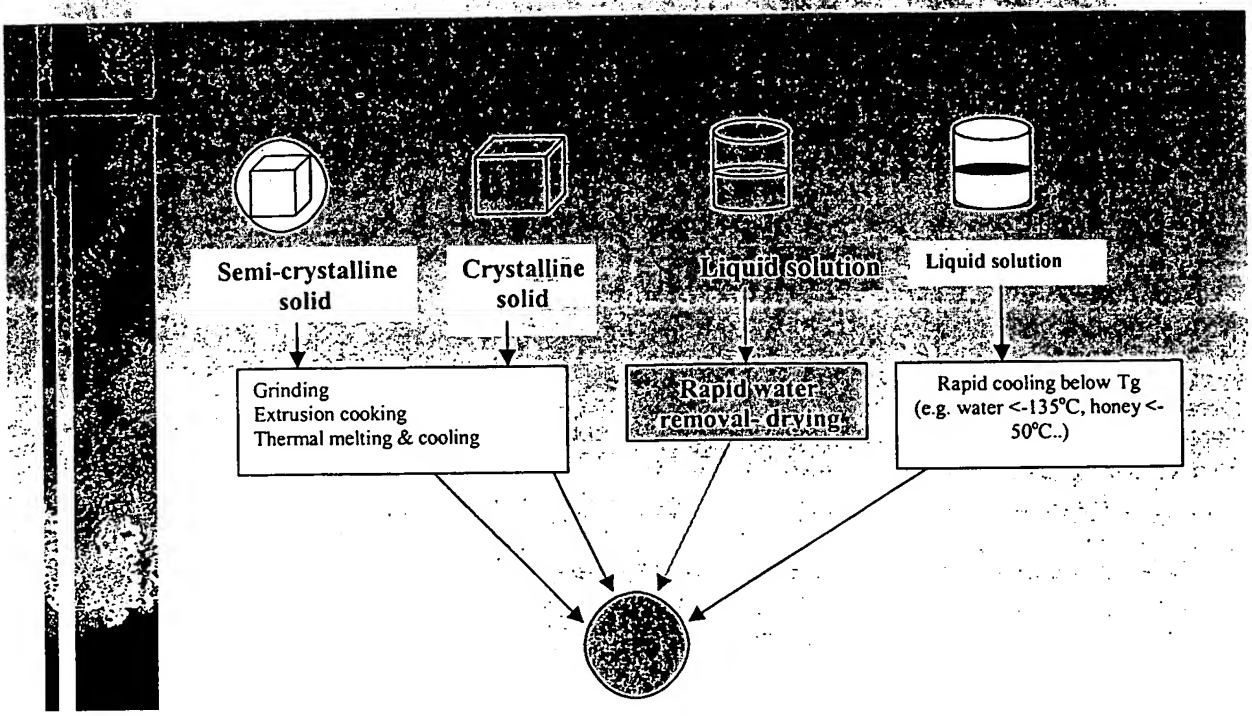
Sugars	Hygroscopicity (relative)	Melting point (°C)	Approx solubility in H_20 60°C (%,w/w)	Tg (°C)	Stickiness (relative)
Lactose	+	223	35	101	+
Maltose	++	165	52	87	++
Sucrose	+++	186	71	62	+++
Glucose	+++++	146	72	31	+++++
Fructose	++++++	105	89	5	++++++

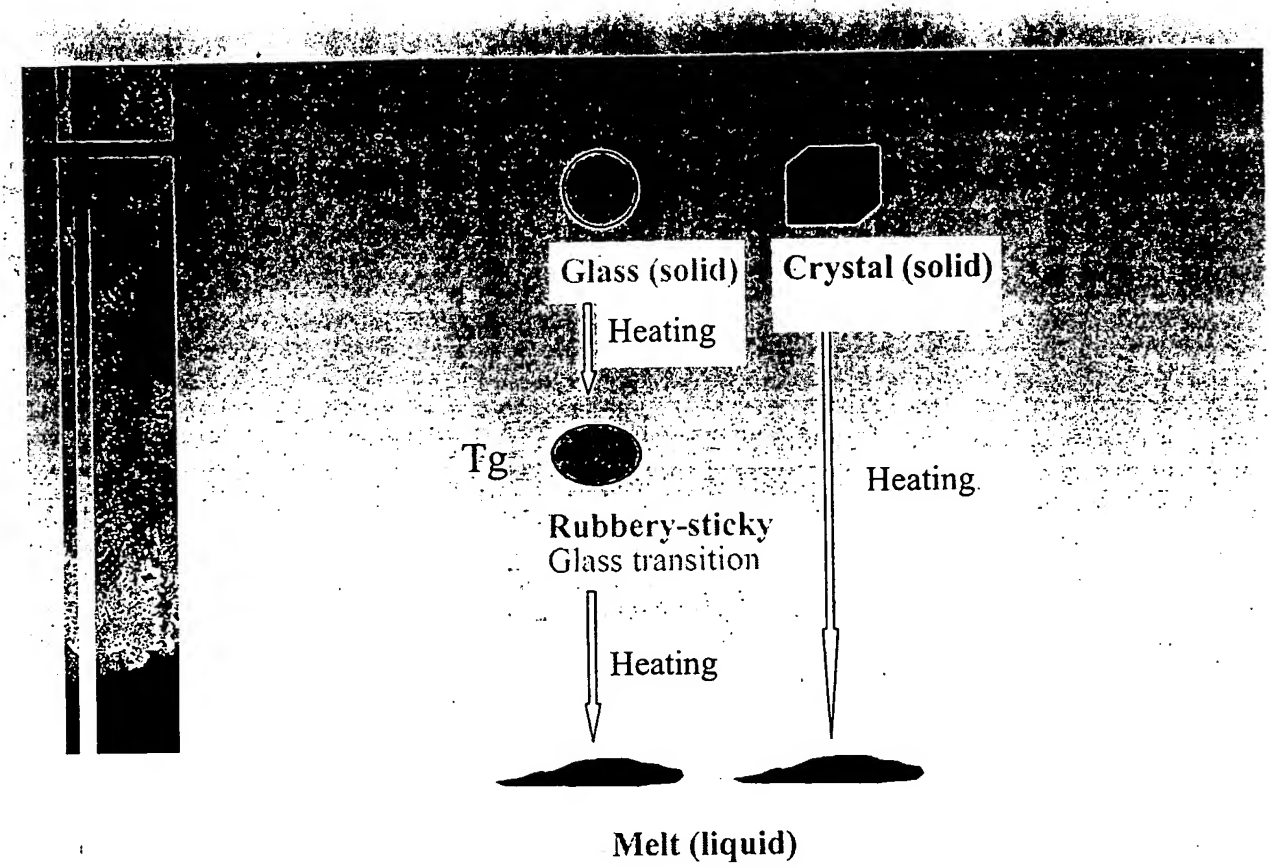
What is a glass transition?

Physical states of dried or drying solid materials:

- **Amorphous**
  - non-aligned molecular structure
  - very hygroscopic
  - go through glass transition
  - predominant in dried food

- **Crystalline**
  - aligned molecular structure
  - non hygroscopic
  - no glass transition


Semi-crystalline solid
Crystalline solid
Liquid solution
Liquid solution
Grinding
Extrusion cooking
Thermal melting & cooling
Rapid water removal- drying
Rapid cooling below Tg (e.g. water <-135°C, honey <-50°C..)
Amorphous solid (glass)


Glass (solid)
Crystal (solid)
Heating
Tg
Heating
Rubbery-sticky
Glass transition
Heating
Melt (liquid)

General concepts

- If the product temperature is above its glass transition temperature (Tg)- it will exhibit stickiness
- Shorter chain molecules- low glass transition temperature (Tg of monosaccharides<Tg of disaccharides)
- Water depresses the Tg significantly (Tg of amorphous solid water is -135°C)
- For a complex food system, the Tg is a function of weight fraction of each component and their Tgs'- but the relationship is not linear

Glass transition temperature of various food materials

Food materials	T_g (°C)[abc]
Fructose	5
Glucose	31
Galactose	32
Sucrose	62
Maltose	87
Lactose	101
Citric acid	6
Tartaric acid	18
Malic acid	-21
Lactic acid	-60
Maltodextrins	
DE[d] 36 (MW=550)	100
DE 25 (MW=720)	121
DE 20 (MW=900)	141
DE 10 (MW=1800)	160
DE 5 (MW=3600)	188
Starch	243[e]
Ice-cream[f]	-34.3
Honey[g]	-42 to -51

Glass transition related problems in various drying processes

- **Spray drying**: sticking on the drier wall, duct and cyclone, poor recovery of powder, agglomeration in the collection bag or container
- **Freeze drying**: "Collapse" of structure while drying
- **Coventional hot air solid drying**: poor fluidisation, stick on the drying racks/shelves, soft product while drying but solid after cooling
- **Storage**: Clumping, agglomeration, caking, crystallisation

Some solutions

- Drying below the glass transition temperature (often not feasible)
- Choosing mild drying temperature conditions
- Increasing the Tg of the food by adding high molecular weight materials (such as maltodextrins)- a predictive approach according to the composition
- Immediate cooling of the product below its Tg
- Appropriate drier design to suit the sticky product

Conclusion

- At the glass transition temperature the amorphous food is converted to rubbery state (from its solid glassy state)
- If the temperature of the product is above its glass transition temperature it exhibits stickiness
- The stickiness can be minimised by lowering drying temperature and increasing the Tg by adding high molecular weight additive
- An optimisation procedure is needed to control the Tg of the product and to select correct drying conditions